Some Results from the Swedish "Albatross" Cruise[1]

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SIX YEARS AGO, late in November, 1947, the Swedish research ship, the 1,450-ton motor schooner "Albatross," on its round-the-world cruise entered the harbor of Honolulu, where we had a magnificent reception. Two years later, in December, 1949, I was invited over here from the Mainland to give a preliminary survey of the main results of the cruise obtained through work in the Oceanographic Institute in Göteborg and in collaborating institutes in Sweden and abroad to that time.

Now, 4 years later, I am happy to say that fair progress has been made in this work, so that already some volumes of our "Reports from the Swedish Deep-Sea Expedition" have been printed, and more are coming.

We have also had the satisfaction of seeing other deep-sea cruises, sent out from Denmark, from Great Britain, and from the United States, working on the lines the "Albatross" followed, partly with aid of the technique developed in Sweden, and also that their results have on several important points confirmed our own.

I shall now give a summary of the results gained since I was here last, particularly those in submarine geology.

A glance at a map of the world which indicates the depths of the oceans will show you immediately why the Pacific Ocean, and especially its central parts, are the cherished hunting ground of deep-sea oceanographers. Here is the greatest area of ocean deeper than 4,000 metres, or 13,000 feet. From these depths the Hawaiian Islands rise as great mountains.

Our cruise here through the equatorial Pacific Ocean, from the Galápagos Islands to the Philippine Islands, crisscrossing the equatorial current system, took us 5 months to accomplish, one third of the time alloted for our whole cruise. The course we followed is shown on the map accompanying my earlier article in Pacific Science (2[4]: 231–238). Between Tahiti and Oahu we followed the course of H.M.S. "Challenger," made over 70 years earlier, but in the opposite direction. Here Sir John Murray had found indications of the sediment having accumulated with extreme slowness. Here, therefore, the piston corer, invented and manipulated on board by Dr. Kullenberg, would be likely, with its maximum range of 60 to 70 feet, to penetrate further backward in time than anywhere else.

Thanks to radioactive age-determinations made in Göteborg on different sediment layers in our cores, we are now able to say that the Mid-Pacific Red clay increases in thickness by about 1 millimetre in 1,000 years. This implies that, for adding 1 inch to the sediment carpet in that area, some 25,000

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years of uninterrupted sedimentation are required.

Only a few words about these radioactive age-determinations, as applied to submarine chronology. Some 15 years ago I ventured to explain the mysteriously high radium content of the Red clay and of the Radiolarian ooze as due to a precipitation onto the ocean bottom of radium's mother element, ionium, together with ferric hydroxide. Granting this to be true, the content of "ionium-supported" radium in the deposit should decrease with increasing distance below the sediment surface at a rate correlated with the half-period of ionium decay, that is, to 50 per cent in 83,000 years, to 25 per cent in 166,000 years, etc. This presupposes that there is no sensible amount of the ancestral element, uranium, present in the deposit. Both assumptions, a lack of uranium and a surplus of ionium near the sediment surface, have been confirmed recently through investigations on "Albatross" cores by Professor F. Hecht in Vienna and by Dr. E. Picciotto in Brussels, whereas Dr. V. Kröll in Göteborg has carried out most of the radium determinations.

However, age-determinations from radium measurements alone are not such a simple, straightforward work as the ionium-precipitation hypothesis would lead us to believe, possibly because of radium's tendency to migrate downward in the sediment column, leaving behind its more stationary mother-element, ionium.[3] Although this makes the technique more complicated, it is still possible, with due precautions, to use measurements of the vertical distribution of radioactivity along a sediment core as a means of determining its past rate of deposition.

There are, however, also other, more indirect methods for attacking the difficult problem of submarine geochronology, for example, the dating of different sediment layers. One of these methods depends on a careful analysis of the calcareous Foraminifera shells present in different strata and the presence of more or less heat-loving or "thermophile" species. This really amounts to a paleoclimatological study of the temperature variations in the surface layers of the ocean which have become reflected in the plankton organisms it has contained. In this manner, indications by the "thermometer" which a sediment core represents can be linked up with known and datable variations in the temperature on the continents due to cold (glacial) and warm (interglacial) ages. This, so to say, biological age-determination was first extensively used on cores from the German "Meteor" expedition by W. Schott and later on "Albatross" cores by Schott in Göteborg, by C. D. Ovey in London, and especially by F. Phleger, F. Parker, and J. Pierson in the Scripps Institution of Oceanography in La Jolla.

The geologist of our expedition, Dr. G. Arrhenius, a year ago published a comprehensive study of the "Albatross" cores from the eastern Pacific Ocean. In this pioneer work of great importance to deep-sea research, Arrhenius has very carefully compared different sediment components such as carbonate of lime, humus-carbon, nitrogen, phosphorus, iron, manganese, titanium, etc. In this manner and utilizing also the biogenic components, Arrhenius was able to correlate the different strata in cores from very wide regions and to ascribe these strata to different stages and substages of continental glaciation. Assuming titanium to be the least variable of all the inorganic components in the deposits, Arrhenius calculated the rate of accruement of titanium to the sediment from the "lutite veil," that is, the finest clay-particles suspended in ocean water. In this manner he calculated the "titanium age" of the different layers in different cores. He further obtained a basis for this chronology from measurements by the radio-carbon dating method made in collaboration with F. Libby and Kjellberg of

[3] Recent ionium determinations in our Red clay samples do not lend support to this migration hypothesis, except possibly as a contributory influence on the radium distribution in the cores.

the rate of deposition in a certain core from the region considered. Arrhenius also drew inferences from his core analyses regarding the intensity and location of the equatorial current system during the Quaternary Age. Not all Arrhenius' conclusions are accepted by other workers in the field, especially not the titanium-age calculations. Recent discoveries of an unexpectedly high titanium content in certain metamorphosed rocks on the Hawaiian Islands appear to make it more difficult to accept any conclusion regarding a constant rate of accruement of this element to the bottom sediments. Nevertheless, the thesis published by Arrhenius is of outstanding value to future work on deep-sea geology.

There are some aspects of our results which I consider to be of particular interest. One of these regards submarine volcanism. It is well known that the Pacific Ocean, both in its peripheral and in its central parts, has been an area of extensive volcanic activity and that its numerous islands have largely been built up from submarine volcanoes, the most monumental of which are these islands of Hawaii. The "Albatross" cruise afforded ample evidence that submarine volcanic action has also worked in a horizontal direction, producing extensive lava beds on the ocean floor.

For many years I have been of the opinion that submarine volcanic activity must also have had important geochemical effects by releasing magmatic volatiles like carbon dioxide and mineral acids and that these have been active in dissolving away the lime from calcareous oozes and transforming them into Red clay and Radiolarian ooze. This would explain how these sediments can have been formed during the Tertiary Age when the temperature of the bottom water in great ocean depths must have been much higher than at present and when no Antarctic Bottom Current, generally held responsible for the dissolving away of the lime, swept over the ocean floor. That Red clay of Tertiary Age, formed under these conditions, actually exists in great depths was first proved by the long cores raised by the "Albatross." Some prominent geologists and oceanographers, such as W. Rubey and R. Revelle, have argued that the water filling the ocean basins has also been largely derived from magmatic volatiles released from the substratum beneath the ocean floor.

It seems to me that the central Pacific Ocean, especially the vicinity of the Hawaiian Islands, affords an ideal field for testing this hypothesis, a view I found strongly supported by the late master of volcanology, Professor T. Jaggar.

A most important fact learned from the "Albatross" cruise, afterward confirmed from other expeditions, is the unexpectedly high geothermal gradient in the deep-sea deposits, quite as high as, if not even higher than, the average value for the continents. It seems reasonable to assume that the supply of geothermal energy below the ocean floor may be a sign of an extensive "latent" volcanism, whatever the ultimate source of this accumulated geothermal heat may be.

Two more of our results appear to me worthy of being mentioned here. Thanks to co-operation with our great authority on explosives, Professor W. Weibull of the Bofors Armament Works, we were able during the cruise to measure, for the first time, through a seismic method the thickness of the sediment carpet spread over the ocean floor. Geochemical speculations by eminent authorities had given 7,000 feet as a probable average value for the thickness of the Red clay, with higher values for other, more rapidly accumulating sediments. Weibull's reflexion measurements gave comparable, in one case even higher, values for the central Atlantic Ocean between Madeira and the Mid-Atlantic Ridge. But to our great surprise the values found in the central Pacific and also in the Indian Ocean were only a small fraction of the theoretical figures. This latter fact has been amply confirmed through later measurements by refraction shooting methods used both from the British research ship "Challenger" and from the "Capricorn" and other expeditions sent out from Scripps Institution. So far no explanation for this surprisingly small thickness of sediment in the Pacific Ocean, generally assumed to be the oldest sea basin, has been proposed. Possibly a conversion of already deposited sediment layers into magmatized crusts through submarine volcanic activity may be considered, or else an extenuation of the seismic waves through intermediate lava layers may be assumed.

Finally I have to mention a great puzzle to deep-sea geologists which consists in the displacement of already deposited sediments through submarine erosion or other agencies. Investigations on the Radiolarians in "Albatross" cores, especially such from the central Pacific Ocean, carried out in Göteborg by a young Australian scientist, W. Riedel, have proved that in some localities Radiolarians of recent origin are mixed with such of Tertiary age. Similar observations on Foraminifera have been made in the Atlantic Ocean by Phleger, working on "Albatross" cores, by Ericson working on Atlantic cores raised from the "Atlantis," and on Pacific "Albatross" cores by Brotzen. On the other hand, by means of optical methods developed by Jerlov during the "Albatross" cruise, it has proved possible to find evidence of submarine erosion due to bottom currents sweeping over ridges or banks. To assign all such cases or sediment transportation to the so-called turbidity currents studied by Kuenen and others does not appear a sufficient explanation.

Our fond hopes that the deposits from great ocean depths constitute records which have remained undisturbed for millions upon millions of years are obviously not always in accordance with established facts. However, to infer from this fact that deep-sea coring only gives falsified abstracts from the "records of the deep" is a false conclusion. Already Arrhenius' pioneer work on cores from the eastern Pacific Ocean has proved what valuable results the study of long sediment cores can give for increasing our highly limited knowledge of the sediment carpet in great ocean depths. I believe this will become still more evident when, within a few years, the "Reports from the Swedish Deep-Sea Expedition" will have appeared complete in print.

When the "Albatross" was here in December, 1947, I emphasized in a lecture held before the Honolulu Chamber of Commerce that your city has an unrivaled position for the study of the deep ocean floor and for unraveling its secrets. I am happy to find now that this view has been gaining support from leading men of your University. I have had great pleasure in finding also what important work is being carried out from the new Marine Laboratory on Coconut Island and by the U. S. Fish and Wildlife Service on your campus, with results which admirably supplement our hydrographic sections across the Equatorial Current System. I sincerely hope that when I come here again, as I hope to do, there will be a new centre for deep-sea research in operation here, and with this wish I beg to thank you for having listened to my exposition tonight.